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This report summarizes the results associated with instrumentation purchased under DURIP contract F49620-98-1-0263 in support of AFOSR/DARPA MURI Program on "Multivariable Control, Simulation, Optimization, and Signal Processing for the Microlithographic Process". This project is generally concerned with the application of systems techniques to the lithographic sequence used for patterning integrated circuits at very small dimensions (less than 250 nanometers). This complex sequence is comprised of photoresist processing, mask design, and optical illumination steps. Lithography is a major technological area that may impede the continued increase in integrated circuit density (Moore's Law).

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Final Technical Report

Equipment for Multivariate Control, Simulation, Optimization, and Signal
Processing for the Microlithographic Process

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Submitted to:
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AFOSR/PKC
801 N. Randolph St., Room 732
Arlington, VA 22203-1977

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Summary

This report summarizes the results associated with instrumentation purchased under DURIP contract F49620-98-1-0263 in support of AFOSR/DARPA MURI Program on "Multivariable Control, Simulation, Optimization, and Signal Processing for the Microlithographic Process". This project is generally concerned with the application of systems techniques to the lithographic sequence used for patterning integrated circuits at very small dimensions (less than 250 nanometers). This complex sequence is comprised of photoresist processing, mask design, and optical illumination steps. Lithography is a major technological area that may impede the continued increase in integrated circuit density (Moore's Law).

The equipment purchased in this program was used primarily for the development of an advanced thermal processing station for manufacturing integrated circuits utilizing acid catalyzed photoresists for deep-ultraviolet photolithography. This process is quite sensitive to temperature (ranging from 2 to 10 nanometers per degree Celsius). Consequently, stringent temperature control is required. We have developed temperature control algorithms and patented gear for conducting these most thermally sensitive steps. This technology has been transferred through a licensing arrangement with Stanford University to a company APT Systems, that has transitioned it into a commercial-grade product. The first productized system was successfully delivered in July, 2000, to a major manufacturer of photomasks with several follow-on orders scheduled for delivery later this year. The purpose of the technology is to place stringent controls on the photomask processing temperature trajectories, thereby enabling highly sensitive photoresists to manufacture advanced photomasks. The basis for the system was an analysis of the thermal characteristics of large volume substrates to show that nonuniform local heating was needed to achieve uniform heating at the substrate plane. Further analysis showed that decoupling the heating modes into independent rapidly responding units was required to achieve fast response times with minimal out-of-plane stress-induced deformation. The resulting technology is a major departure from conventional heating systems since it utilizes high dimensional multivariable spatial control to manipulate the temperature field over a small grid. The system is nearly two orders of magnitude faster than conventional equipment (response times of 20 seconds versus 2000 seconds) and provides an order of magnitude improvement in spatial controllability (625 mm^2 local heating fields versus 18,000 mm^2 fields). Further, the system provides an in-situ quench capability that had never been achieved in the industry. This adds-up to a system with extreme temperature control capabilities, providing advantages in yield, throughput and across-substrate electronic performance. This precise method of temperature control may also find use in other areas, such as independently controlling all linear in-plane distortion modes for precision overlay.

The instrumentation purchased under this program was used in demonstrating the thermal array concept. It included the fabrication of the unit, the implementation of computerized data acquisition and thermal sensors, and the addition of a robot to test the repeatability of the system. The overall system was stationed at ETEC Systems in Hillsboro, OR,

from 6/99 - 12/99 for application on photomask processing. This system is shown in Figure 1. The temperature control results taken at ETEC are shown in Figure 2.

Figure 1: Picture of the thermal cycling system in operation in a cleanroom at ETEC Systems in Hillsboro, OR.
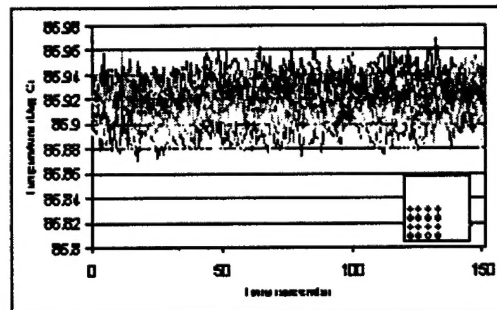

Figure 2: Temperature uniformity at steady-state as measured by 16 RTD's positioned in a quadrant of a 6-inch square quartz photomask.

2DTA432 Summary of Expenses

Requisition #	Amount	Vendor	Date Written
H92194	$2,125.97	Marchi-Norman	06/14/1999
UN2171	$1,056.97	Automation Plus	04/05/1999
UL4093	$411.35	Yuhas Tooling	02/08/1999
H58061	$39,450.24	Polytec,PI	01/20/1999
UK7774	$1,108.48	Yuhas Tooling	01/20/1999
UK3950	$162.38	Campbell Tool & Metal	01/07/1999
H54811	$7,838.81	Melles Griot	01/06/1999
H54823	$32,138.58	Hewlett Packard	01/06/1999
H54830	$3,230.23	National Instruments	01/06/1999
H53573	$1,940.58	Instrument Lab	01/06/1999
H46993	$20,910.00	Genmark	11/23/1998
UH8114	$432.31	Force Electronics	11/10/1998
UH7600	$103.40	Ted Pella Inc	11/09/1998
UH0395	$1,423.43	National Instruments	10/15/1998
H32649	$2,380.42	Fry's Electronics	09/23/1998
UG0918	$1,480.86	Newark Electronics	09/17/1998
H10277	$11,230.40	AG Associates	06/19/1998
H08691	$15,344.44	Sun Microsystems	06/15/1998
Indirect Costs	$5,099.59		
TOTAL	$147,868.44		